Mapping Forest Damage Due to the Southern Pine Beetle in the Daniel Boone National Forest Using Landsat Data

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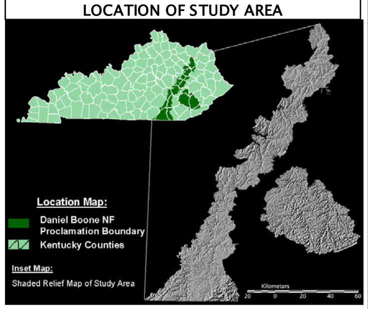
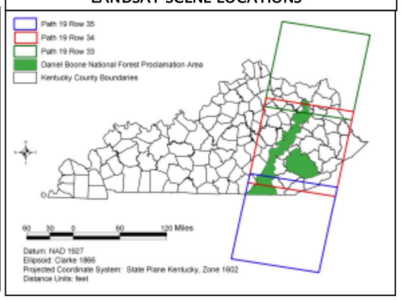
INTRODUCTION AND RESEARCH GOAL

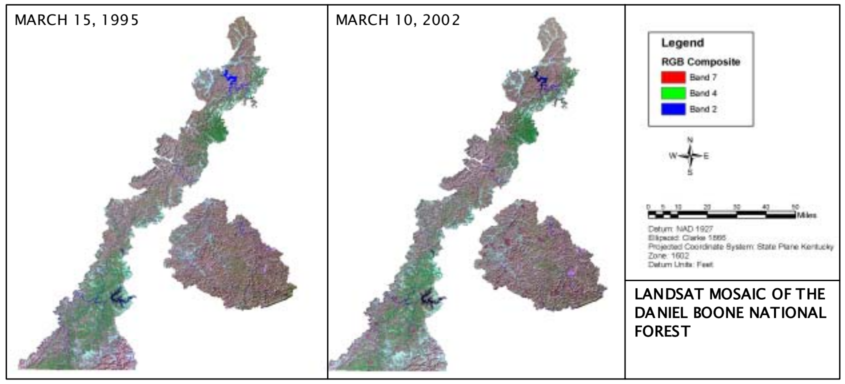
This study was conducted in the Daniel Boone National Forest (DBNF), Kentucky. The goal of the research was to map the extent and magnitude of forest damage by the southern pine beetle (*Dendroctonus frontalis* Zimmermann) within the Daniel Boone National Forest. The SPB is one of the most important causes of damage and mortality to pine trees in southeastern United States. Infestation by the SPB was first reported in the DBNF in spring 2000. This study utilized Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) data for forest damage mapping.

LOCATION OF STUDY AREA



LANDSAT SCENE LOCATIONS





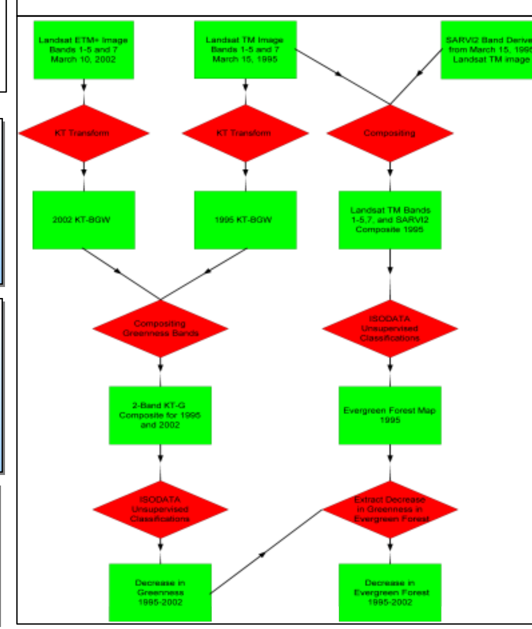
LANDSAT MOSAIC OF THE DANIEL BOONE NATIONAL FOREST

DATA

A total of six Landsat TM and ETM+ images representing the "pre-" and "post-" southern pine beetle infestation period were purchased from the US Geological Survey. Pre-SPB infestation period Landsat TM images were acquired on-board Landsat 5 on March 15th 1995, while the post-SPB infestation period landsat ETM+ images were acquired onboard Landsat 7 on March 10th 2002.

Other data used in this study included color infrared photography acquired in July 2001, a 30-feet Digital Elevation Model (DEM), point and polygon data of SPB infestation spots obtained from ground-truth field surveys and aerial sketch mapping by USFS personnel.

IMAGE PROCESSING STEPS FOR MAPPING SPB DAMAGED FORESTS



REMOTE SENSING AND FOREST DAMAGE ASSESSMENT

Remotely sensed data have been used successfully to detect and assess forest damage in a variety of forested landscapes. The most commonly used techniques for mapping forest damage have included image ratioing, image differencing, vegetation indices, merged principal components analysis, spectral-temporal image classifications, post-classification differencing, and Kauth-Thomas transformations. All these methods require the use of a pre- and post- forest damage image. In this study, we used Kauth-Thomas transformations in combination with single date image classifications to map SPB forest damage.

RADIOMETRIC AND ATMOSPHERIC CORRECTIONS

Each satellite image was subjected to radiometric and atmospheric corrections using the dark object subtraction method (DOS) and the COST method. These methods are entirely image-based and have been found to be as accurate as methods that use *in situ* atmospheric field measurements and radiative transfer codes.

GEOREFERENCING

The three Landsat ETM+ images acquired on March 10th 2002 were precision-corrected and did not require georeferencing. However, the "pre-infestation" images acquired on March 15, 1995 were not georeferenced. The first stage in our image processing involved georectification of each of the three Landsat TM image to its corresponding Landsat ETM+ image. Each georeferencing used at least 20 ground control points (GCPs) and resulted in a total root mean square (RMS) error of less than half a pixel (15 feet). A first-order polynomial and nearest neighbor resampling were used in all the georeferencing.

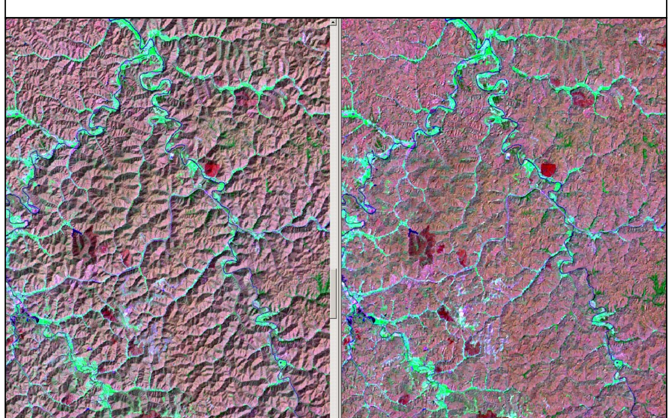
MOSAICKING IMAGES

After georectification was completed the three Landsat TM and three Landsat ETM+ images were mosaicked. Since over 85 percent of the DBNF Proclamation area lies within the image acquired along path 19 row 34 of the WRS 2 system, this image that was made the reference in the mosaic process. The histograms of image subsets acquired along path 19 row 33 and path 19 row 35 were made to match those of the image acquired along path 19 row 34, and the mosaic process initiated. Once the mosaic process was complete, new images that only included the DBNF proclamation area were extracted for 1995 (Figure 2) and 2002 (Figure 3).

SOIL AND ATMOSPHERICALLY RESISTANT VEGETATION INDEX (SARVI2)

The Soil and atmospherically resistant vegetation index (SARVI2) was used together with spectral band data to map the location and extend of evergreen forests. Calculation of this vegetation index requires reflectance data. The formula is

Close-up View of the C-factor Topographic Normalization



A. Before Topographic Normalization — 10 Kilometers

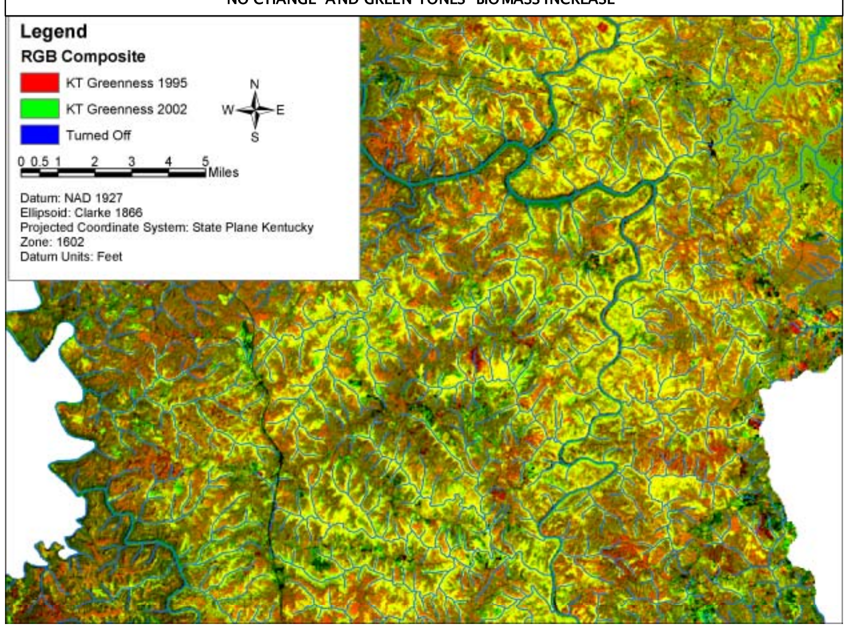
B. After C-Factor Topographic Normalization — 10 Kilometers

TOPOGRAPHIC NORMALIZATION

Topographic normalization techniques strive to reduce differences in illumination for the same land cover types, thereby allowing classification of land cover types with less confusion and more accuracy.

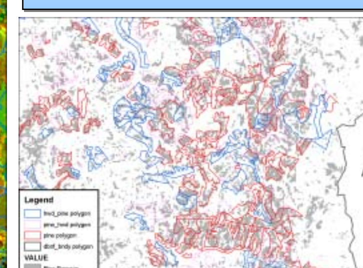
Of the available non-Lambertian methods, the Statistical and C-factor methods are more suited to topographic normalization of forested areas than the Minnaert method. The C-factor method has been found to give slightly better results than the Statistical method and was therefore used to perform topographic normalizations of the 1995 and 2002 mosaic images. The "C-factor" method uses non-Lambertian reflectance models that require estimation of the reflecting properties of the cover types of interest, by a regression of image values against topographic variables

KT-GREENNESS 1995-2002. RED-ORANGE COLOR TONES INDICATE DECREASE IN BIOMASS, YELLOW TONES 'NO CHANGE' AND GREEN TONES 'BIOMASS INCREASE'



RESULTS

Total area mapped as evergreen forest within the DBNF Proclamation boundary on March 15, 1995 was 352,354 acres. On March 10, 2002, the total evergreen forest had been reduced by **144,862 acres**. The decrease in evergreen forest was attributed to pine mortality by the southern pine beetle.



The figure to the left shows pine mortality map for a portion of the DBNF overlaid with pine, pine-hardwood, and hardwood-pine forest stands.

Forest stand data were available only for federally-owned land. Heavy pine mortality also occurred in privately-owned land within the DBNF Proclamation boundary.

CLASSIFICATION ACCURACY ASSESSMENT

275 polygons verified as corresponding to pine stands damaged by the SPB were digitized from georeferenced color infrared (CIR) photos. These polygons were then overlaid on the satellite derived pine damage map to assess the accuracy of the map. 254 polygons were correctly designated as areas of pine mortality on the satellite derived map, yielding an overall accuracy of 92.4 percent.

CONCLUSIONS

Results from this study indicate that Landsat TM and ETM+ data can be routinely used to assess forest disturbance. However, near-anniversary date images are essential in the change detection process. In addition, topographic normalization of the images is essential for project areas with a rugged terrain.

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